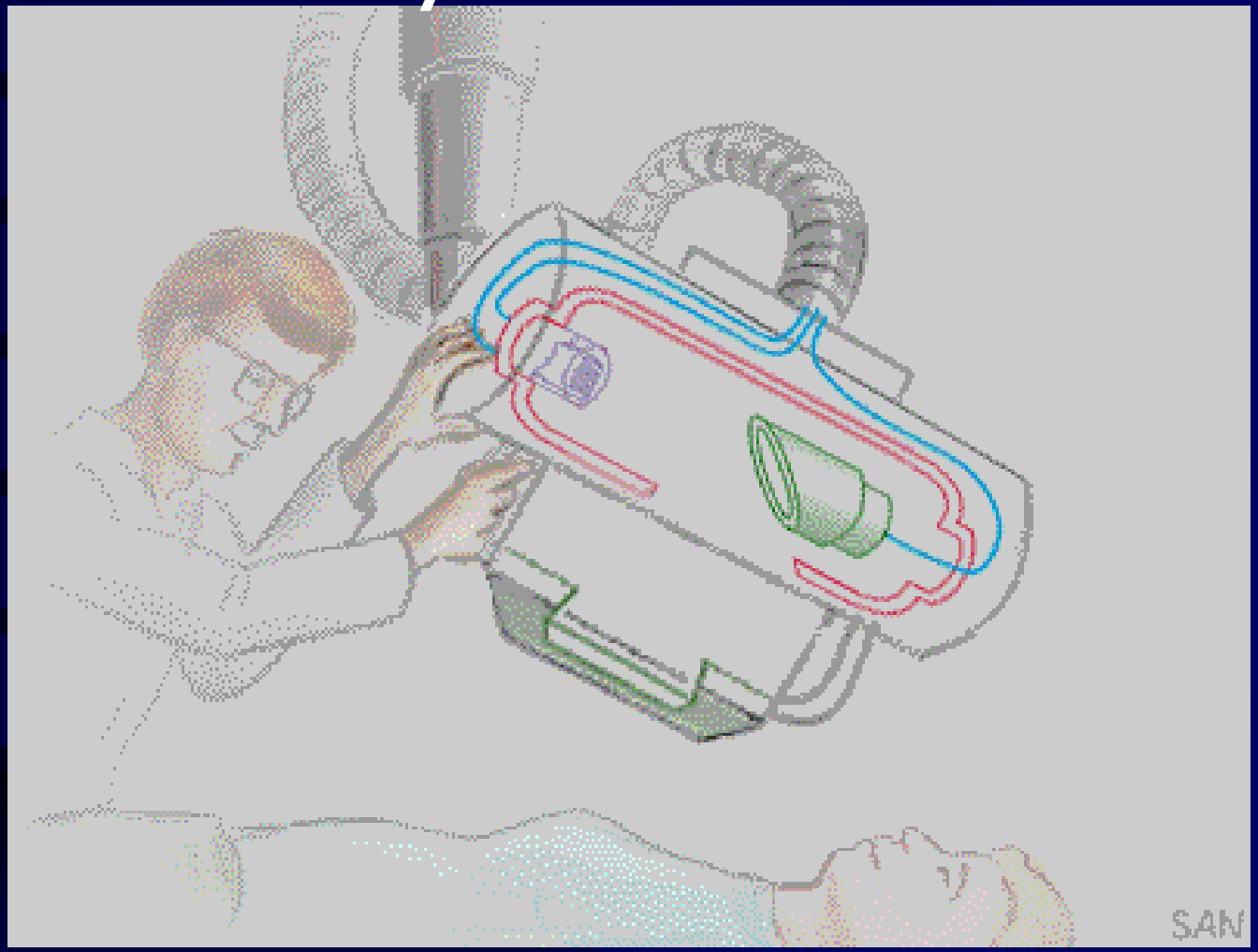
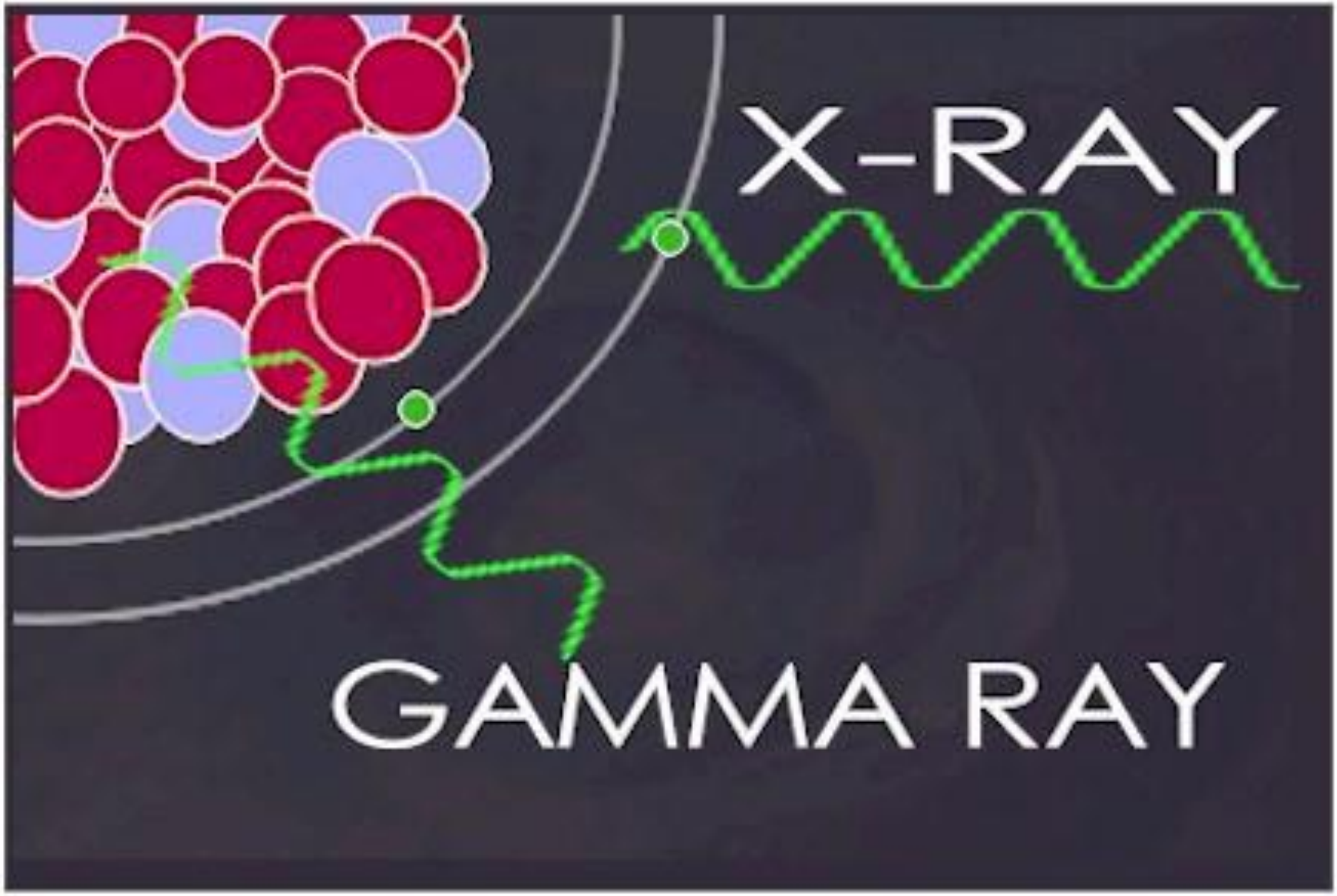
X-ray Production



DR. AMAL ELSHAHAWY


X-RAY
GAMMA RAY

X-rays are one of the main diagnostical tools in medicine since its discovery by Wilhelm Roentgen in 1895.

The classical X-ray tube requires

electron source

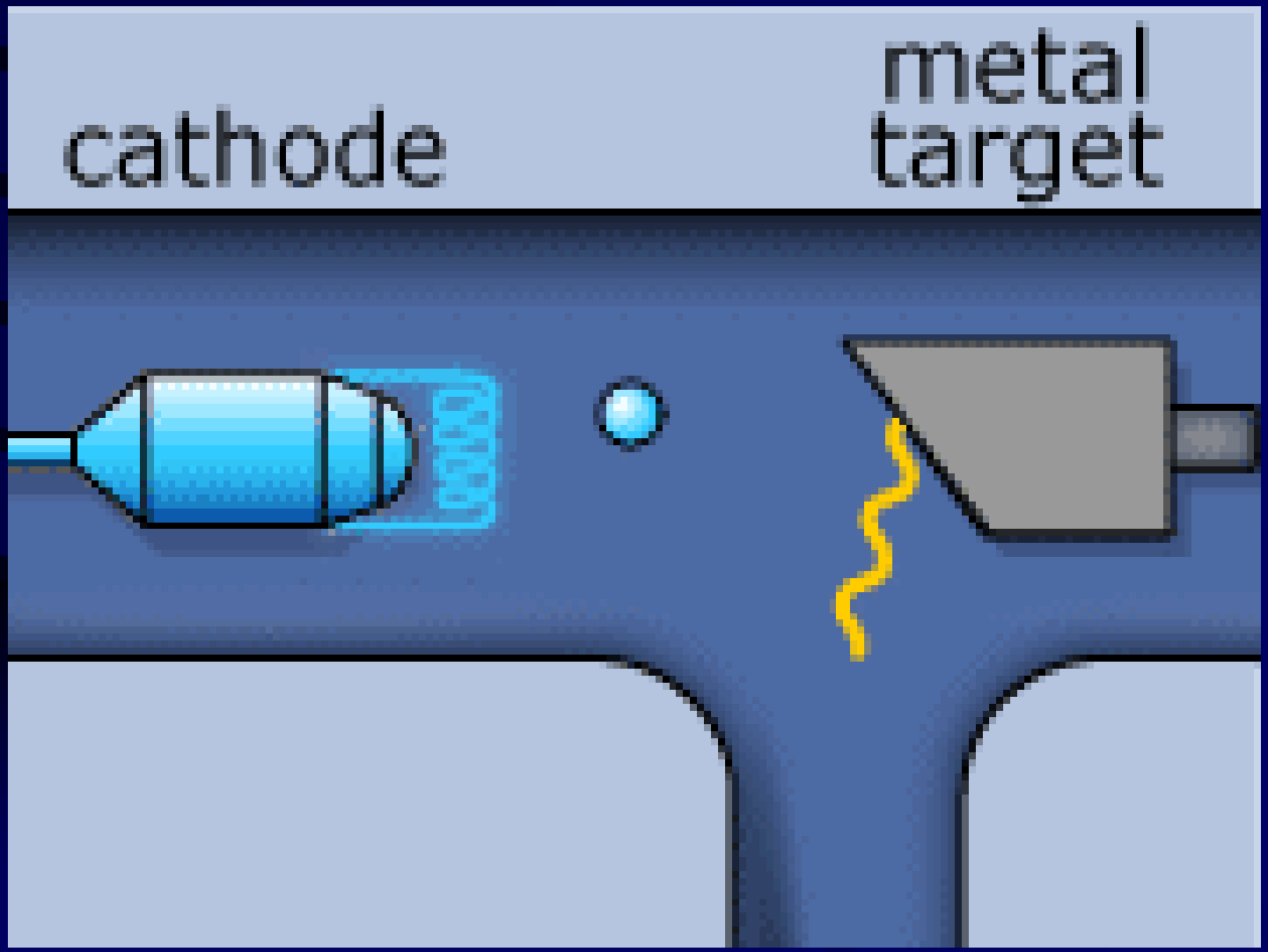
electron acceleration potential

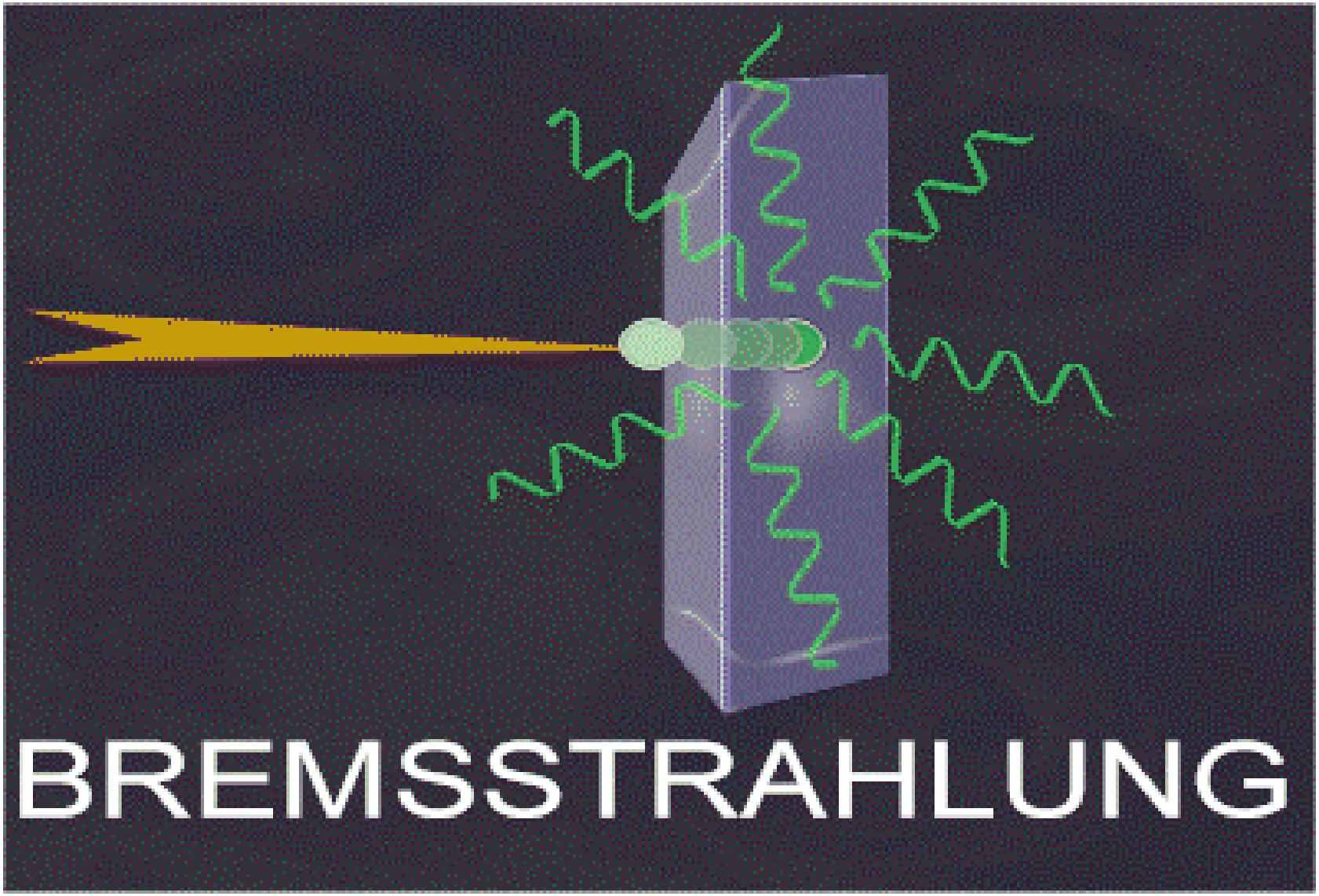
target for X-ray production

Production of X-rays

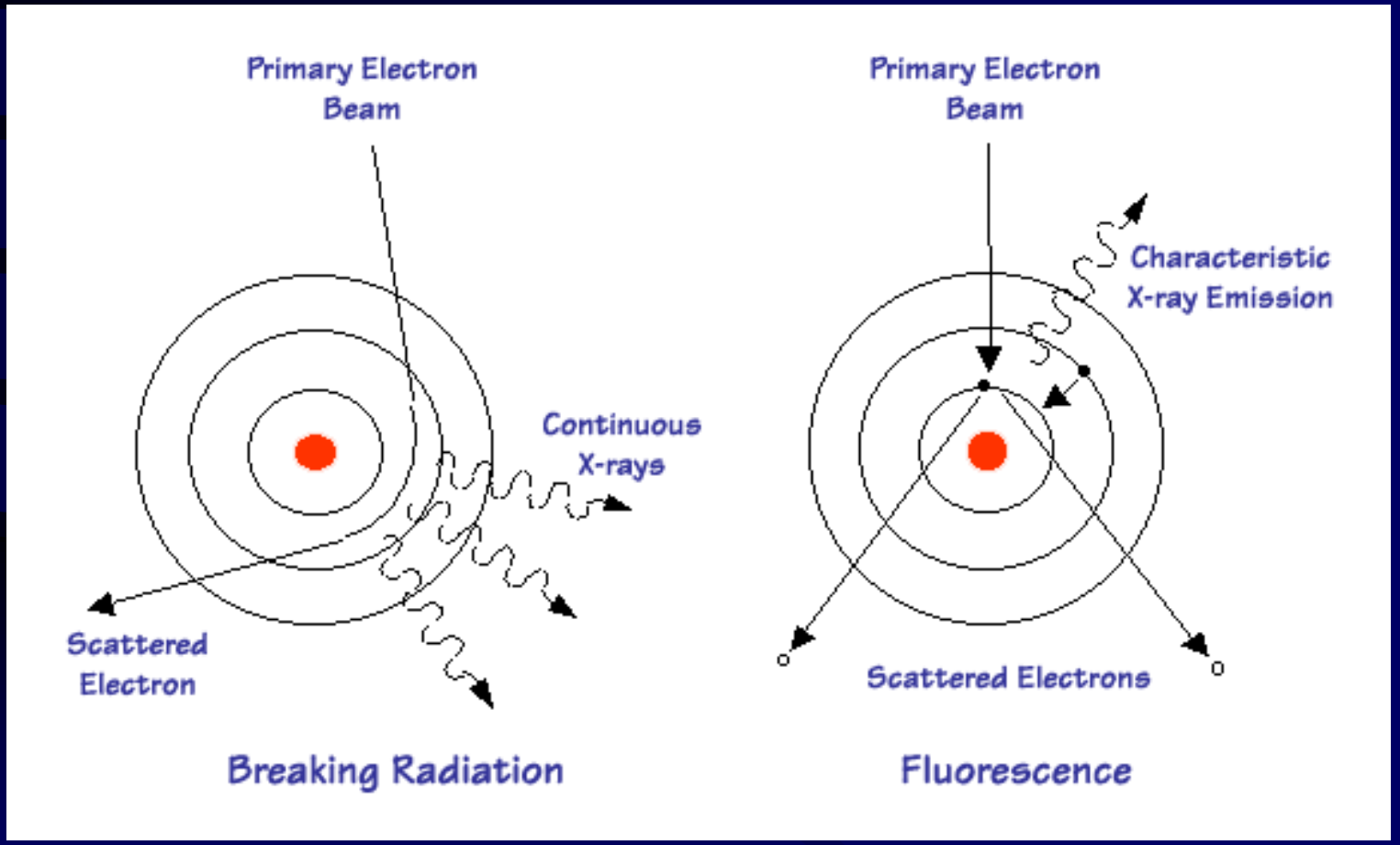
- X-rays are produced when rapidly moving electrons that have been accelerated through a potential difference of order 1 kV to 1 MV strikes a metal target , like tungsten or copper.

X-ray Production




BREMSSTRAHLUNG

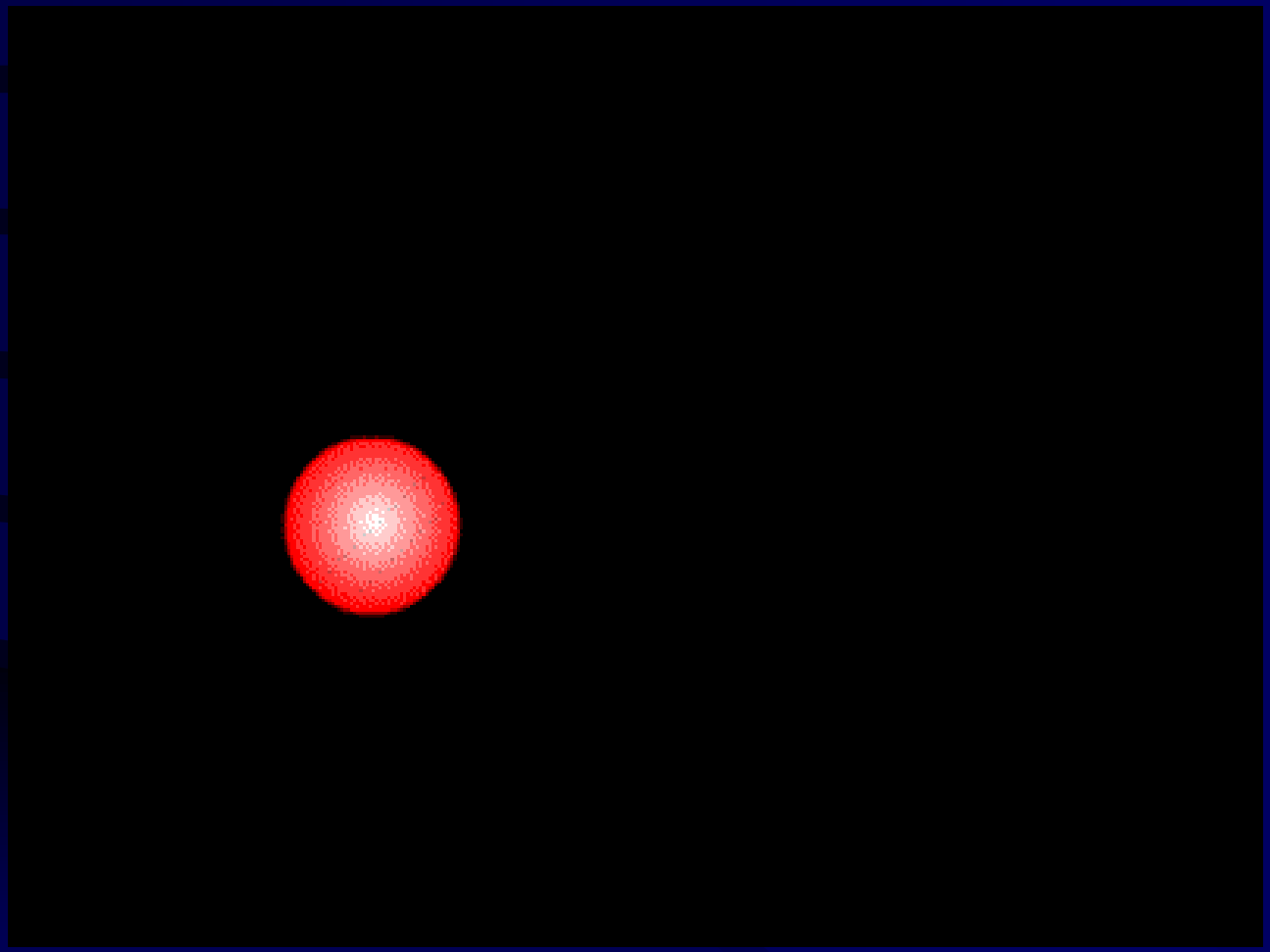
- Where do x-rays come from?
  There are two different atomic processes that can produce x-ray photons. One is called **Bremsstrahlung**, which is a fancy German name meaning "braking radiation." The other is called **characteristic x ray emission**. They can both occur in heavy atoms like tungsten.


Primary Electron Beam
Continuous X-rays
Scattered Electron
Breaking Radiation
Primary Electron Beam
Characteristic X-ray Emission
Scattered Electrons
Fluorescence

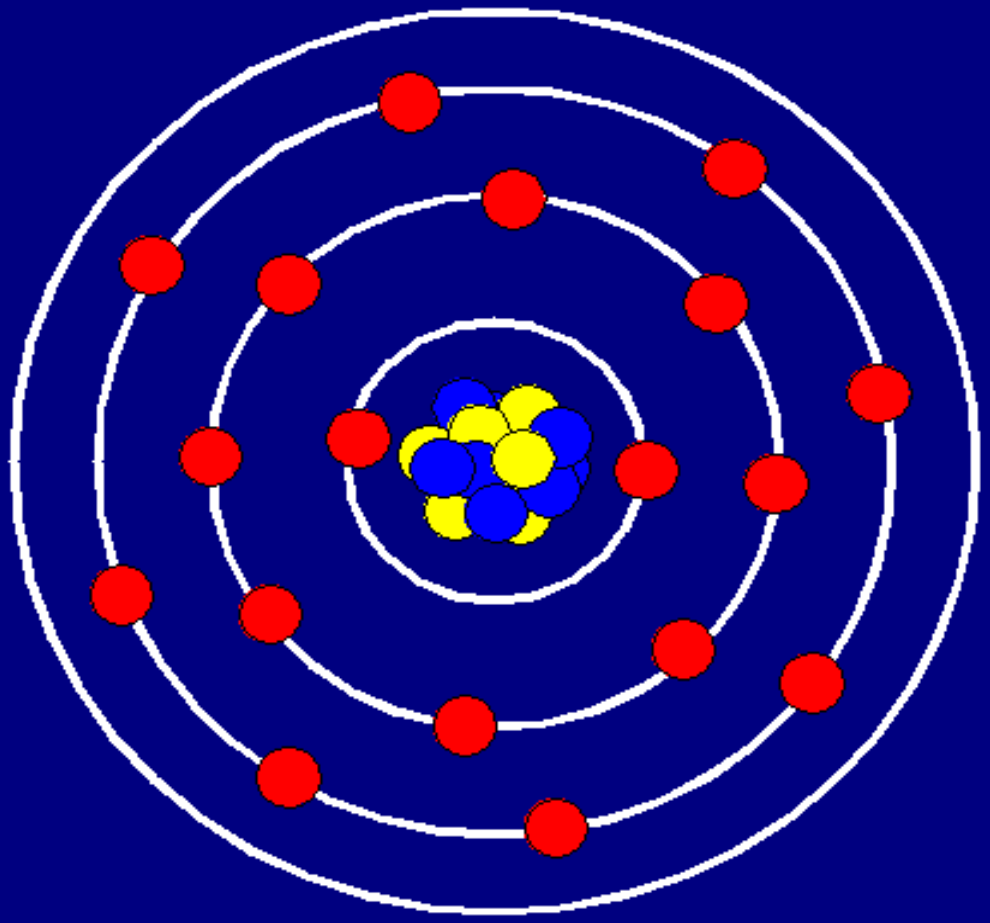
Bremsstrahlung

- some of the electrons will approach the nucleus where they are deflected because of there opposite charges .
- This deflection causes the energy of the electron to decrease, and this decrease in energy then results in forming an x-ray.

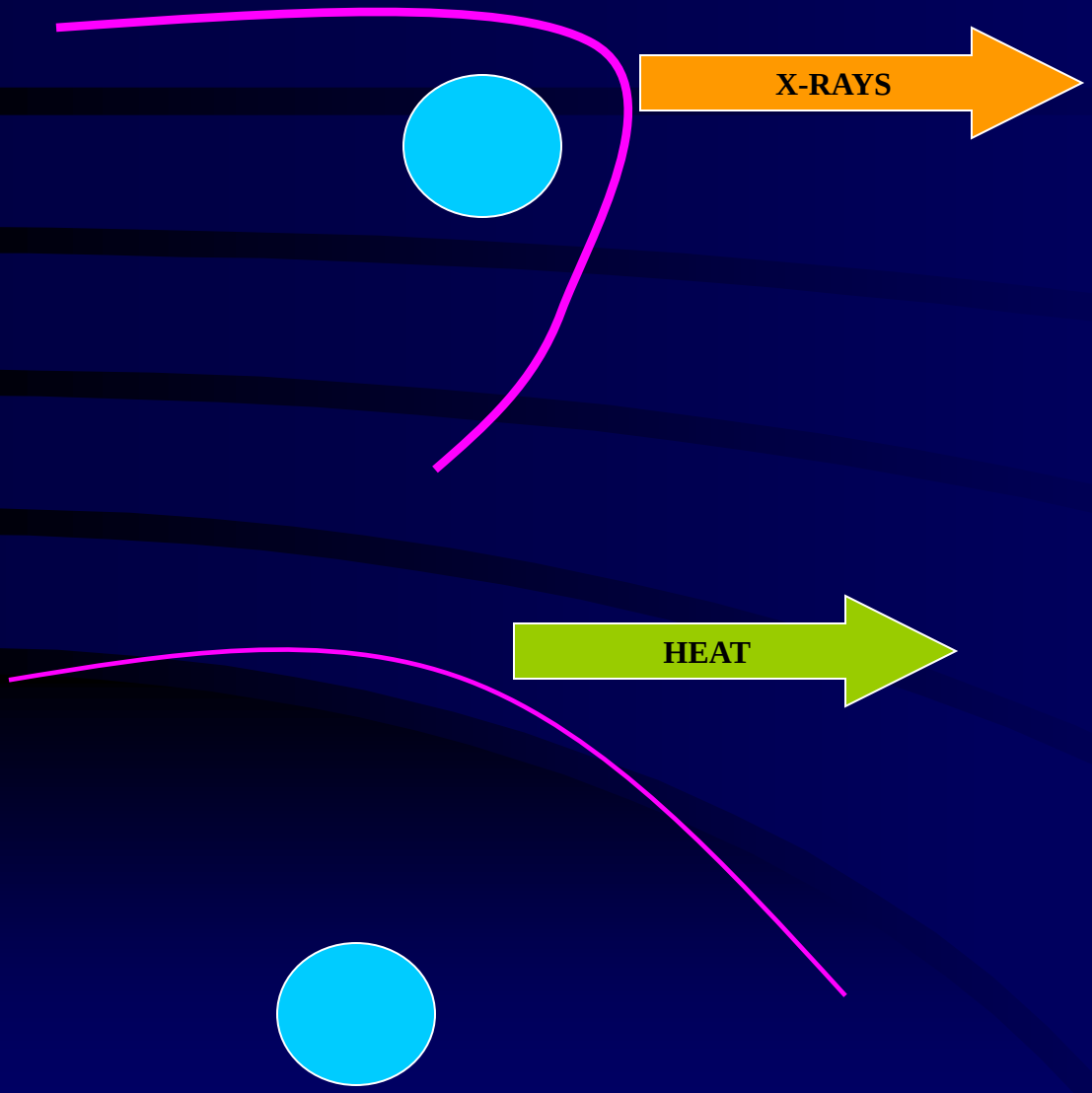
Bremsstrahlung Radiation



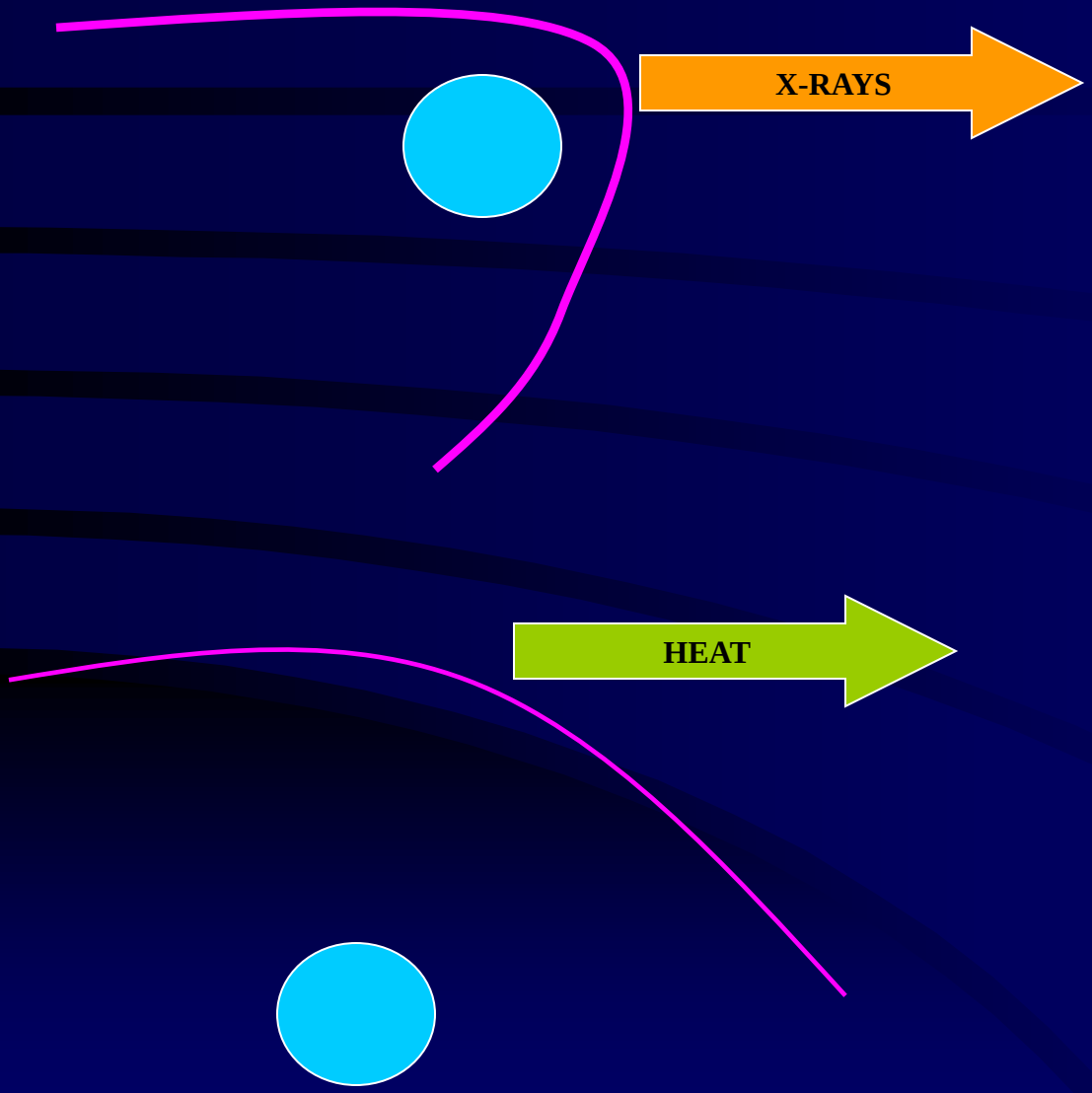
BREMS



DIFFERENT DEGREES OF DECCELERATION



DIFFERENT DEGREES OF DECCELERATION



BREMS RADIATION IS:

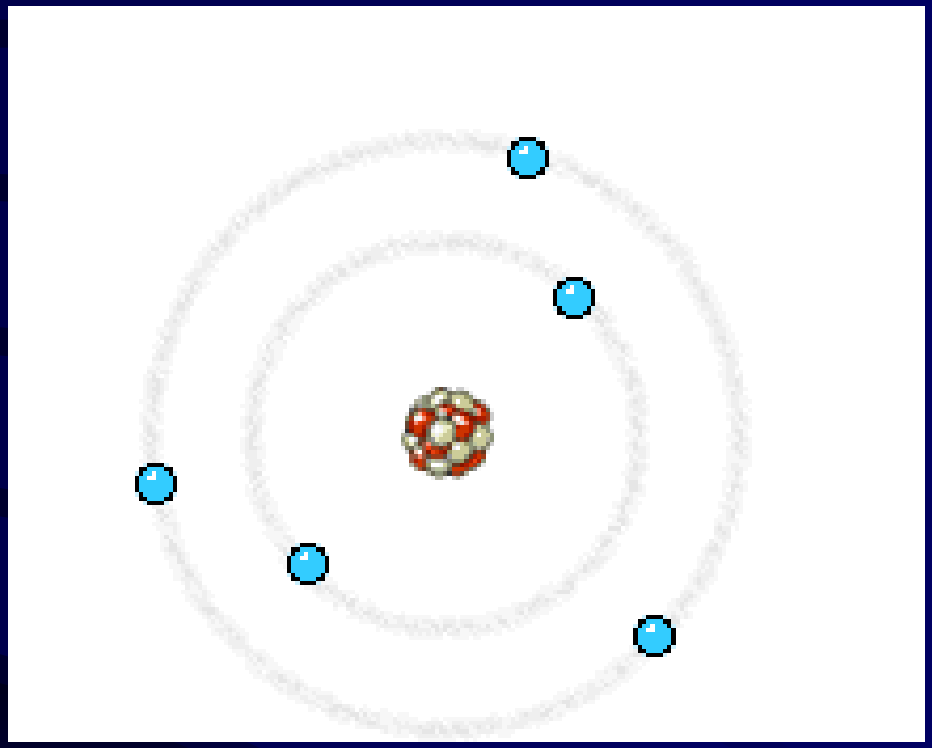
POLYENERGETIC !

90% OF X-RAYS ARE PRODUCED THROUGH BREMS INTERACTIONS WHEN 80-100 KVP APPLIED

Characteristic X-rays

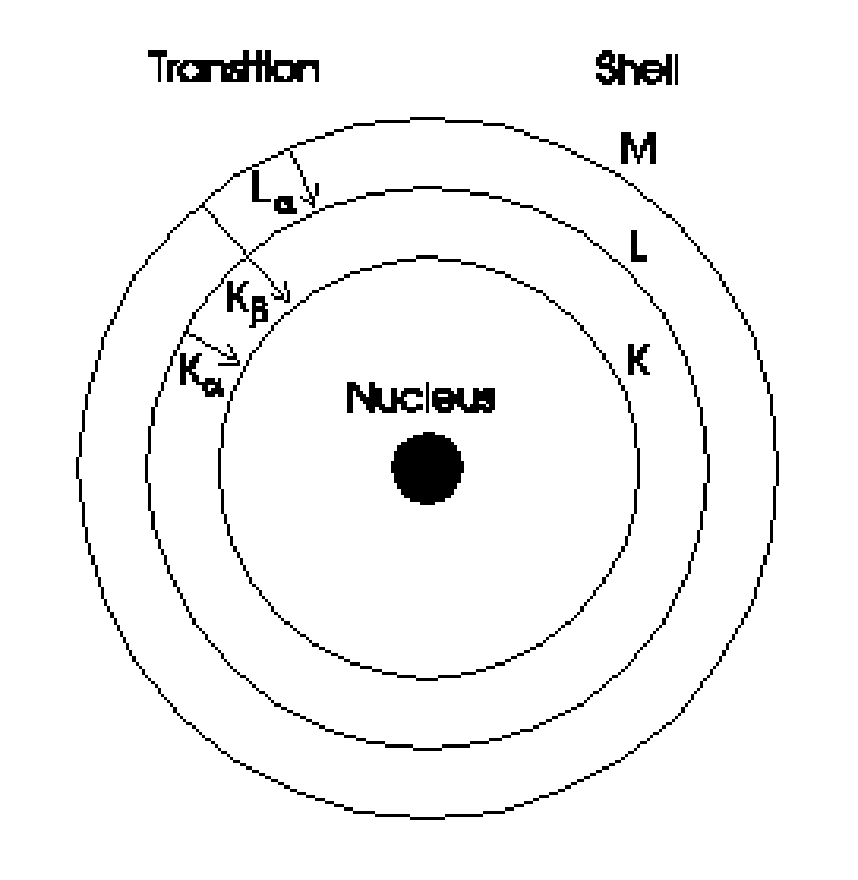
The high energy electron can also cause an electron close to the nucleus in a metal atom to be knocked out from its place. This vacancy is filled by an electron further out from the nucleus. The well defined difference in binding energy, characteristic of the material, is emitted as a monoenergetic photon. When detected this X-ray photon gives rise to a characteristic X-ray line in the energy spectrum.

Characteristic Radiation



KE OF PROJECTILE ELECTRON > BINDING ENERGYORBITAL ELECTRON

CHARACTERISTIC CASCADE

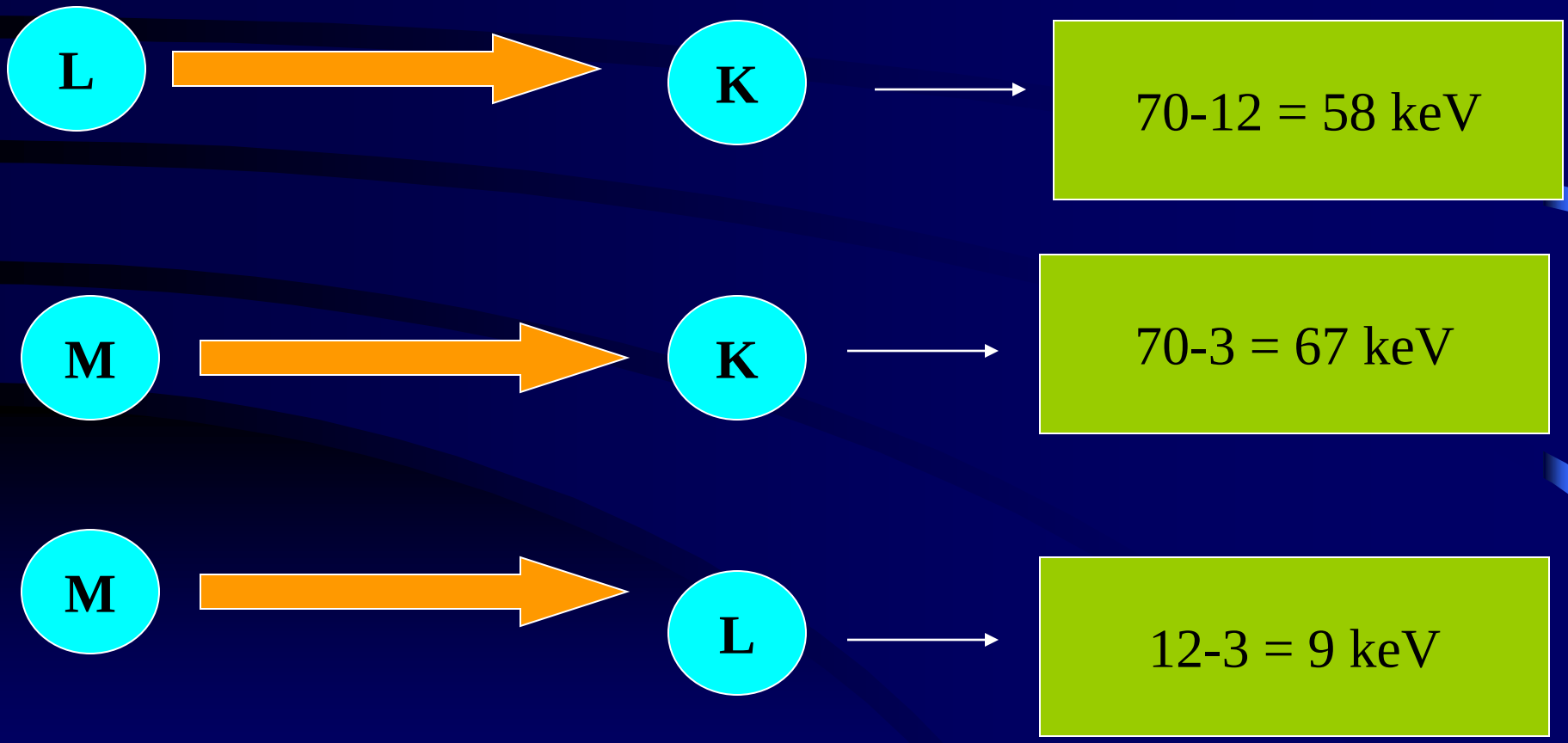


TUNGSTEN-74

BINDING ENERGIES
OF DIFFERENT SHELL ELECTRONS

K-70 KEV
L-12 KEV
M-2.8 KEV

CHARACTERISTIC X-RAYS



TRANSFER OF ELECTRONS BETWEEN OUTER SHELLS RESULTS IN:

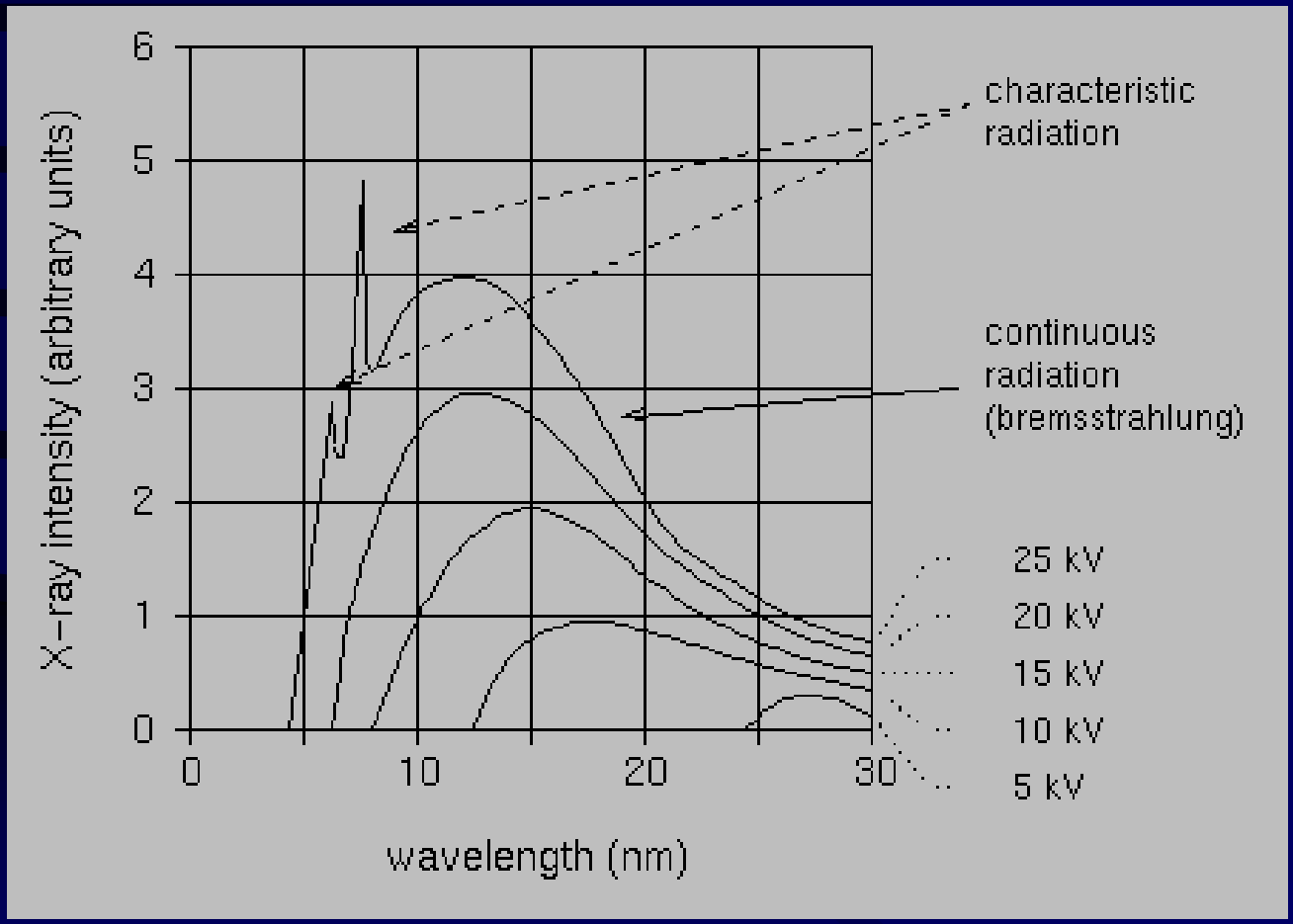
HEAT PRODUCTION !

EACH CHARACTERISTIC RADIATION (ex. K TO L TRANSFER) IS:

MONOENERGETIC !

THERE ARE MANY CHARACTERISTIC RADIATION PRODUCED IN ONE ATOM THEREFORE CHARACTERISTIC RADIATION IS ALSO POLYENERGETIC !

X-ray Spectra



- The graph shows the following features.
  - **A continuous background (continuous spectrum)** of X-radiation in which the intensity varies smoothly with wavelength. The background intensity reaches a maximum value as the wavelength increases, then the intensity falls at greater wavelengths.
  - **Sharp peaks (line or characteristic spectrum)** of intensity occur at wavelengths unaffected by change of tube voltage.

Characteristic X-ray Spectra

- Different target materials give different wavelengths for the peaks in the X-ray spectra.
- The peaks are due to electrons knock out inner-shell electrons from target atoms.
- When these inner-shell vacancies are refilled by free electrons, X-ray photons are emitted.
- The peaks for any target element define its characteristic X-ray spectrum.

- **Why is tungsten used in x-ray tubes? Can't other elements produce x-rays?**
  Most elements emit x-rays when properly bombarded with electrons. Heavier elements (like tungsten) are best because they emit a higher intensity through bremsstrahlung, but there are plenty of heavy elements to choose from.

- The real issue is engineering: Most electrons that hit the tungsten don't do anything special at all -- no bremsstrahlung, no K-shell emission. All of the energy from the electrons' impact then goes into heating the tungsten. Tungsten is used because it can withstand this bombardment, as it has a high melting point and can conduct heat away very well.

X-RAYS PRODUCTION AN INEFFICIENT PROCESS

80 KVP

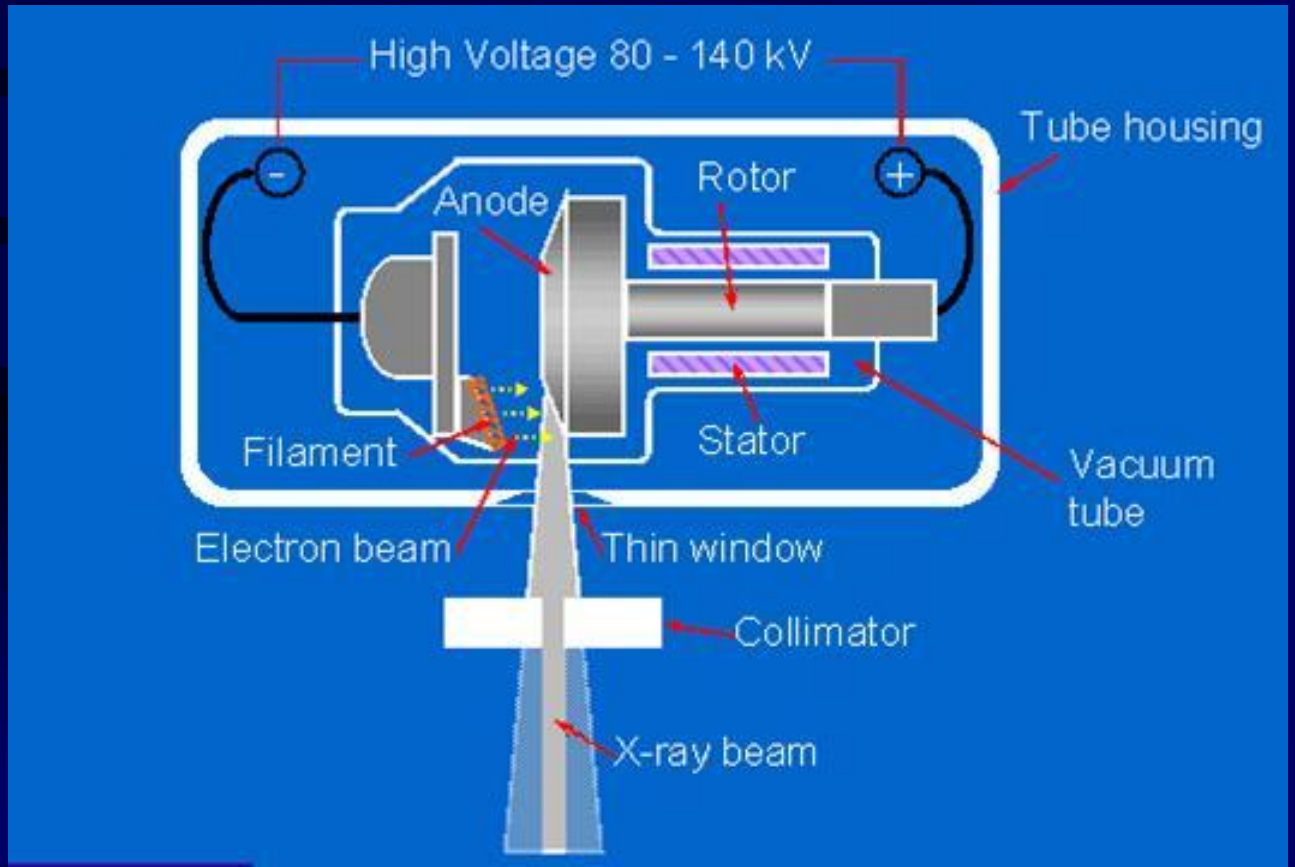
99.4% HEAT 0.6% X-RAYS

% EFFICIENCY OF X-RAY PRODUCTION

% EFFICIENCY= K * Z * kVp

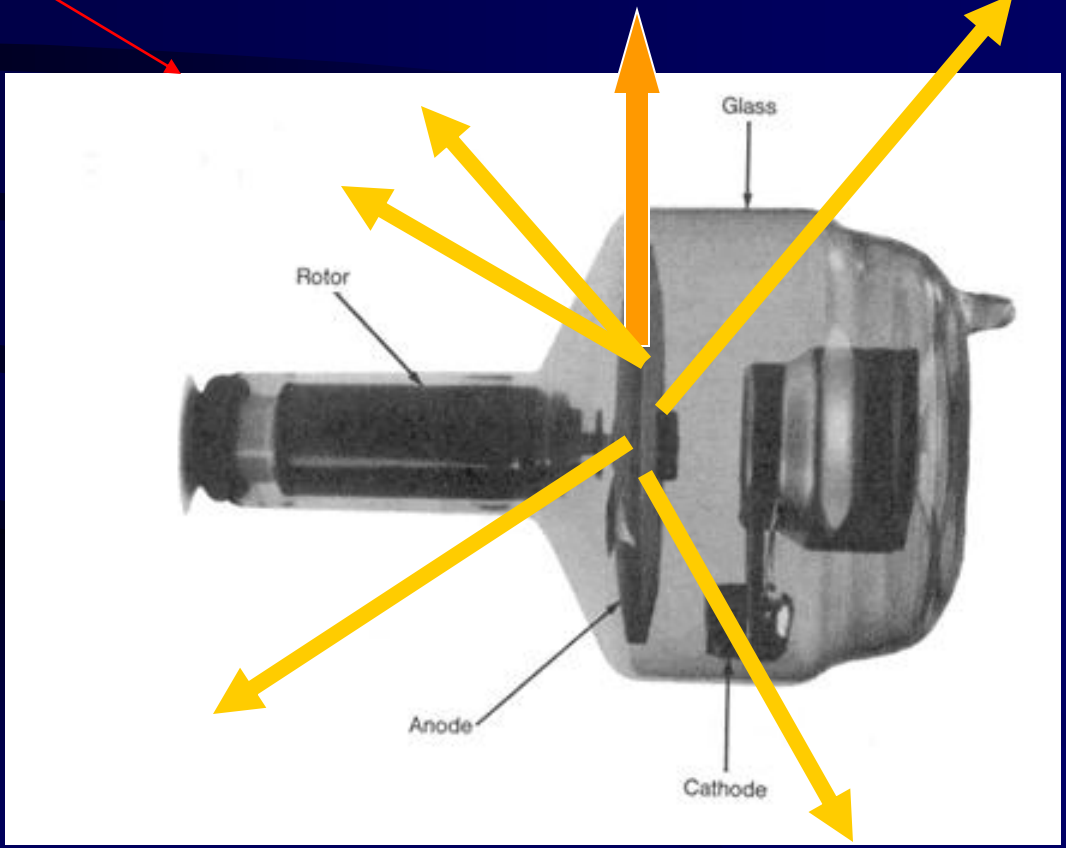
$K = 1 * 10^{-4}$

USEFUL RADIATION – PROJECTED TOWARD THE PATIENT

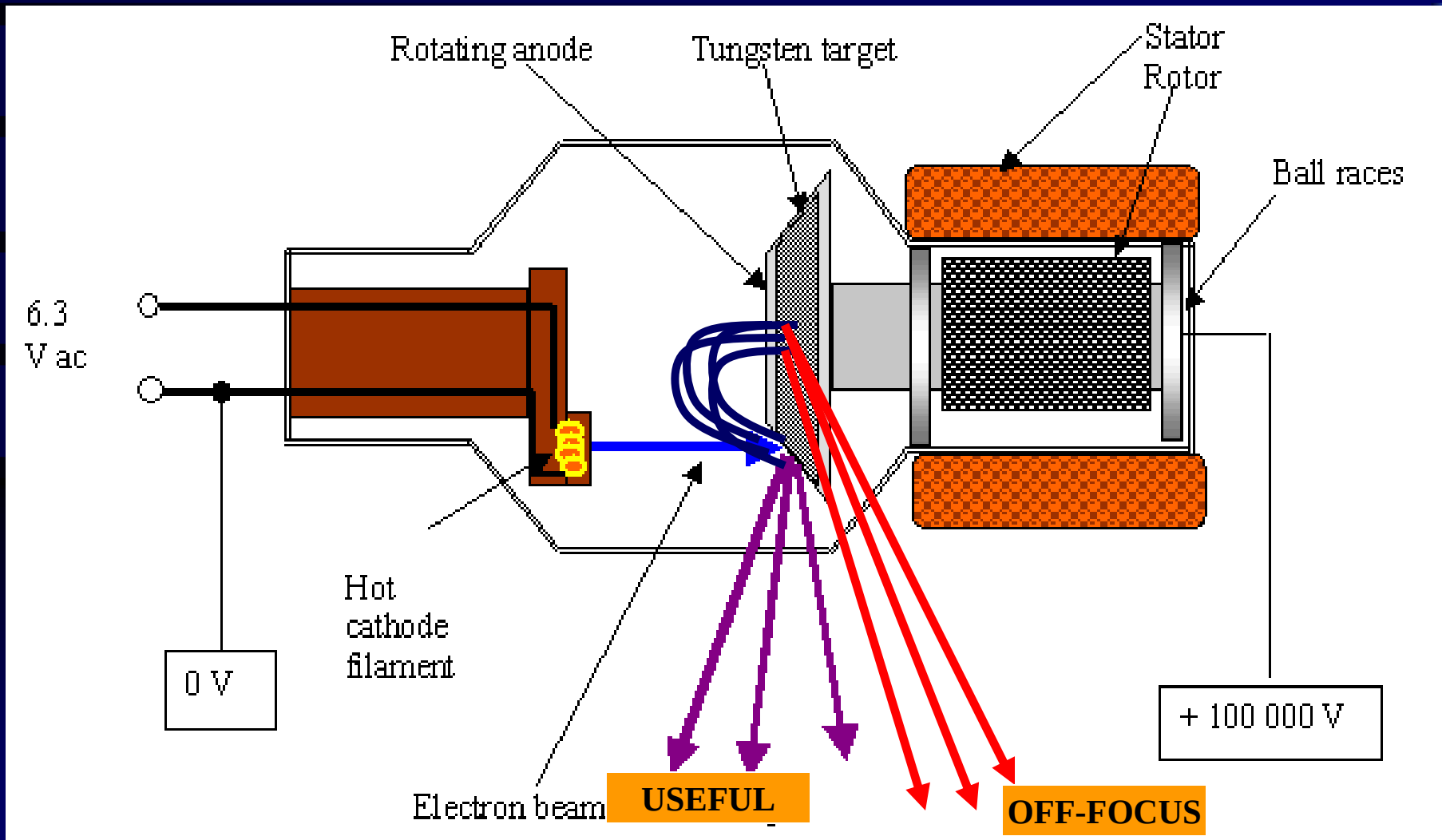


LEAKAGE RADIATION

HOUSING



OFF-FOCUS RADIATION



Uses of x- rays

In medicine

They are used to :-

(a) Locate bone fractures

(b) Destroy cancer cell

(c) To diagnose illness and treatment.

In industry

a) To locate cracks in metals

In crystallography

a) To explore the structure of materials.

In security

a) Used as tool for examining and detection tool to search for arms , airports and banks .

Properties of X-rays

1. X-rays travel in straight lines.
2. X-rays cannot be deflected by electric field or magnetic field.
3. X-rays have a high penetrating power.
4. Photographic film is blackened by X-rays.
5. Fluorescent materials glow when X-rays are directed at them.
6. Photoelectric emission can be produced by X-rays.
7. Ionization of a gas results when an X-ray beam is passed through it.

X-Rays and Gamma Rays

- X-rays are photons (electromagnetic radiations) emitted from electron orbits, such as when an excited orbital electron "falls" back to a lower energy orbit.

- Gamma rays are photons emitted from the nucleus, often as part of radioactive decay.

X-rays and Gamma Radiation

- Gamma rays typically have higher energy (Mev's) than X-rays (KeV's), but both are unlimited.
- No mass; Charge=0; Speed = C; Long range (km in air, m in body); Light damage (QF=1);
- An external hazard (>70 KeV penetrates tissue); Usually shielded with lead or concrete.

Thank you for your attention